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VSOP Observations of the EGRET Blazar 1633+382

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Abstract. Two high-resolution 5 GHz VSOP+VLBA images of the blazar 1633+382 reveal clear morphological change in both the bright inner east-west jet, and in the more diffuse structure further down the jet to the northwest. Here, we discuss the motion of the inner jet as traced by these VSOP images and earlier VLBA observations.

1. Background

The quasar 1633+382 shows a γ-ray bright blazar nucleus (Mattox et al. 1993) with a compact mm-VLBI core whose measured brightness temperature is near the inverse-Compton limit (Krichbaum et al. 2002). Early VLBI observations showed a superluminal pc-scale jet (Barthel et al. 1995) embedded in an unresolved arcsecond-scale core straddled by two faint north-south lobes $\sim 14''$ in total extent (Murphy, Browne, & Perley 1993). Recent VLBA observations (e.g., Fey & Charlot 1997; Jorstad et al. 2001) reveal a predominantly E-W core-jet structure, and a faint extension to the NW which aligns best with the direction of the emission in which the original superluminal motion was tracked.

2. VSOP Imaging of Superluminal Motion in the Jet

Our 5 GHz images of 1633+382 clearly separate the VLBI radio source into two almost equally bright components – the core to the east and the jet extending to the west (Fig. 1). Much more substructure is apparent in the second epoch VSOP observation where much greater maximum projected baselines were reached with the spacecraft, matching the resolution of ground only observations at higher frequencies (e.g. at 22 GHz, Jorstad et al. 2001). This second epoch data (which also used the full VLA) was shared with Lister et al. (2001) as

part of their imaging of the Pearson-Readhead sample with VSOP, and our full resolution image is very similar to their published image so is not shown here.

Our proper motion analysis is limited by the resolution achieved in the first epoch VSOP observation. We modelfitted our data in the u-v plane with DIFMAP, and in the image plane with AIPS assuming a simple double model to fit the core and inner jet component. The best fit positions of the secondary relative to the core are 1.37 mas (July 1997) and 1.56 mas (August 1998) at a position angle (PA) of $-85°$. At higher resolution (Jorstad et al. 2001; Lister et al. 2001), these two features are resolved further making the distance between the most prominent peak in the jet and the core in their maps somewhat greater.

As part of a separate program (Ulvestad et al.), we obtained an earlier (1995) VLBA 8.4 GHz image of 1633+382 (Fig. 1) and can identify the same two inner components as in our VSOP 5 GHz maps, and measured their separation to be 1.01 mas at a PA$=-85°$, consistent with results found by Fey & Charlot (1997) at a nearby epoch. From a 1996 VLBA 5 GHz observation, Fomalont et al. (2000) found a separation of 1.2 mas at the same PA.

Taking these low frequency data together, we can infer a fairly constant motion of about 0.17 mas/yr along a PA$=-85°$ over the period between 1995 and 1999. At z=1.814, this corresponds to $v_{\rm app} \simeq 13c$ ($H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_{\rm M} = 0.3$ and $\Omega_\Lambda = 0.7$). This implies that the jet is aligned at $\leq 9°$ to our line of sight and the Lorentz factor corresponding to the pattern velocity is $\Gamma = 13$ or greater. The epoch of zero separation is thus about 1989.2. This is the same zero epoch of separation inferred from the higher resolution VLBA monitoring of the compact edge of the same dominant jet feature at 22 GHz by Jorstad et al. (2001) where they measured a motion of 0.2 mas/yr also along the E-W direction. For comparison, the early ejection found by Barthel et al. moved 0.16 mas/yr at a more northerly (15° to 25°) projected PA in the sky. Future observations could determine if this current strong long lasting feature will continue in its current E-W trajectory or follow the path of the older emission.

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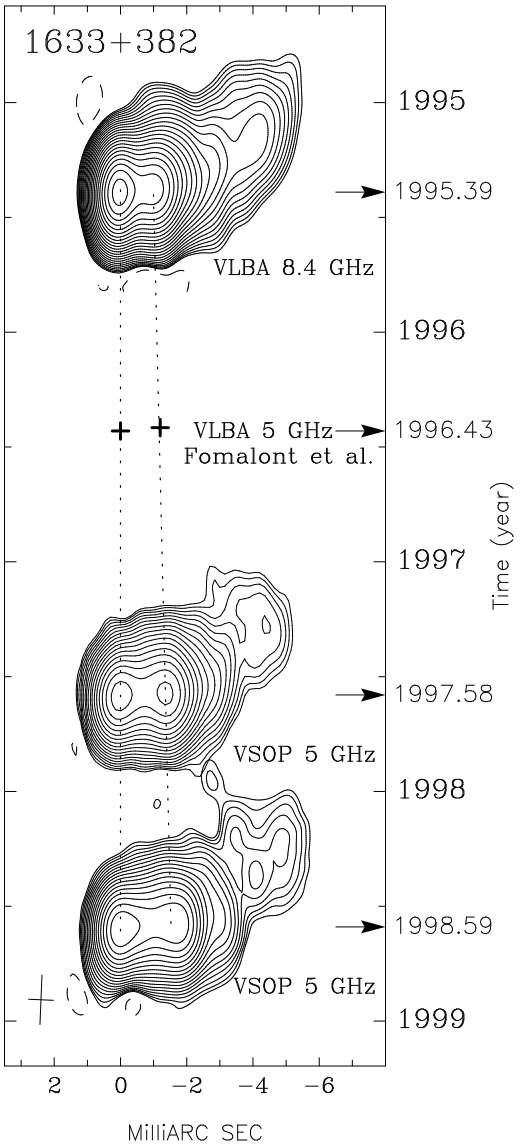

Figure 1. Sequence of VLBI images of 1633+382 convolved with a common beam (bottom left corner) of 1.49×0.75 mas at PA$= -2.42°$ (achieved by the 1997 VSOP data). Contours are spaced by factors of $\sqrt{2}$ with [min, max] levels of [0.4, 819.2] mJy/bm (8.4 GHz image), and [2, 512] mJy/bm (VSOP images). Map peaks are (top to bottom) 0.995, 0.647, and 0.718 Jy/bm. Arrows indicate the observation epochs. Positions of the core and jet component from Fomalont et al. (2000) are indicated with plus signs. The dotted lines trace the 0.17 mas/yr ($\sim$13c) motion of the western jet feature relative to the presumed stationary core.